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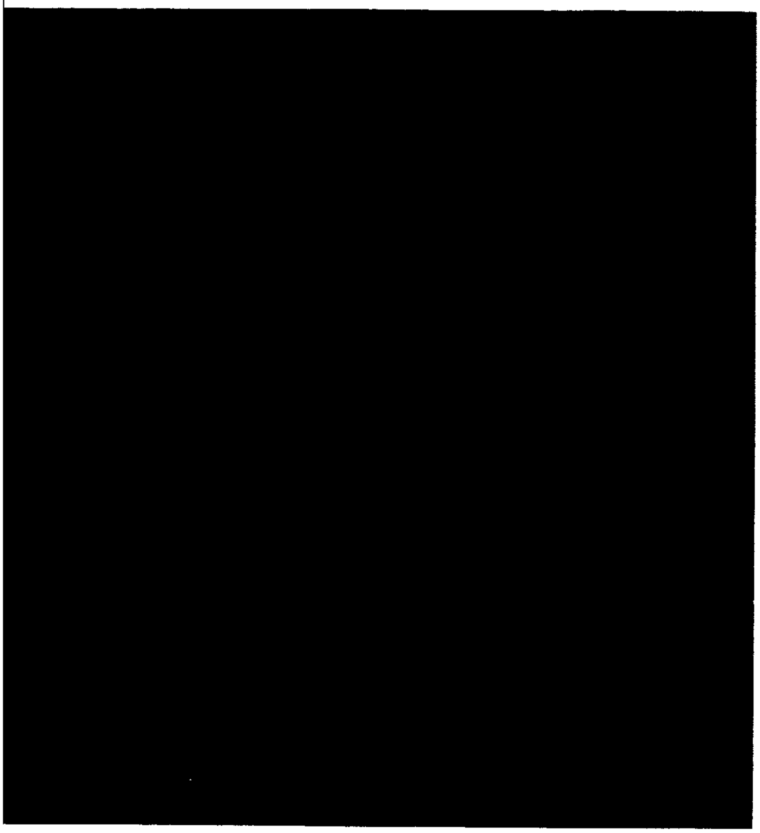
Code

AUTOMATIC DATA PROCESSING



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National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Maryland

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Reprint

Automatic Data Processing*

C. J. CREVELING†, SENIOR MEMBER, IRE, A. G. FERRIS†, AND C. M. STOUT†, MEMBER, IRE

Summary—The problems of reducing telemetry signals from scientific earth satellites are assessed and an account is given of the factors governing the establishment of an automatic processing sequence. Some of the special features of the steps in this sequence are detailed, and an indication is given of the evolution in philosophy which has taken place since processing experience has accumulated. Final mention is given to some of the problems awaiting solution together with some of the plans under development for solving them.

Introduction

WITH THE INCEPTION of earth satellites as a platform for conducting scientific experiments has come a series of related problems concerning the telemetering of the results of these experiments to Earth and the processing of them into suitable forms for the experimenters. There are a number of ways in which satellite telemetry signals differ from those previously dealt with in ground laboratories and ranges. First, the satellite is extremely limited in the amount of weight that can be carried aloft and in the amount of electrical power available. In the earliest projects, weight was generally limited to a few pounds and power was obtained from batteries of the same order of weight or from solar generators of a few watts. As a result the telemetry systems first used were forced to operate at the very threshold, with signals seriously degraded by noise. Although this situation is showing steady improvement, the similarly increasing demands of the experimenters make it unlikely that the luxury of good factors of safety in SNR's will soon be obtained. An urgent concern of any processing system has therefore been to first attempt schemes which would enhance the signal as much as possible before further processing. Since even small gains here have the beneficial effect of increasing the amount of useful data obtained, the net gain is considerable. Techniques used include coherent detection, diversity combining, and matched filter techniques.

Another characteristic of satellite signals is occasioned by their continuous changes in attitude to the observer. The satellite progresses rapidly from horizon to horizon (except for eccentric orbits which have their own problems) and generally is rotating on one or more of its axes. Since theoretical and practical problems limit the antenna pattern to various degrees of anisotropy, it is usual to have the received signal strength varying due to the nulls of the transmitting antenna and to changes in electrical polarization. Further contribution to this effect may be caused by difficulties in training the receiving antenna. As a result, even strong signals frequently are interrupted by regular and irregular periods of fluctuation. Special means must be taken to insure that the ground processes of synchronization are able to cope with these situations to insure minimum interruptions to data when reacquiring synchronization. Various schemes of providing "flywheels" to the sync circuits have been tried with varying degrees of success. These include

1) A narrow-band filter tuned to the sync frequency (bit rate or sampling rate) which will *ring* for some time after disappearance of the signal.
2) A frequency-controlled oscillator at the sync frequency which will *dead-reckon* through nulls.
3) A digital version of the previous scheme using a crystal oscillator and a digital counter with count-up or count-down preset, arranged to adjust itself to the sync frequency and remain unchanged through periods of no signal.
4) More complicated combinations of the previous schemes.

Another salient feature of satellite data is its quantity. Even the smallest satellite in a close orbit of the Earth may have several experiments multiplexed on the telemetry signal. In making 15 or fewer revolutions about the earth each day, they will generally produce a minimum of 15 records, each lasting some 8 minutes and recorded on magnetic tape. In a few months' time this will result in several thousands of tapes to be reduced. With satellites having orbits of high eccentricity, such as Explorer XII, the satellite may hover over one area of the Earth's surface and be *visible* for periods of many hours at a time, producing as many as 8 tapes per hour at as many as 6 stations at one time. If recorded full time, such a satellite might produce 50,000 to 70,000 tapes per year. Since there have been as many as 24 projects at the Goddard Space Flight Center alone, resulting in several major satellite launchings per year, there have been periods when telemetry signals from several satellites required attention at once.

It quickly became obvious in planning the data reduction facilities at the Goddard Space Flight Center that automatic processes would have to be used in handling these quantities of data, rather than the manual and semiautomatic methods which had been used for previous rocket shots which were of limited duration. It was considered that the most powerful and versatile approach would be to translate the data into digital form and process it in large-scale general-purpose digital computers or in special computers designed for this kind of work. With little experience on which to base our calculations, it was

* Received February 27, 1962.
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estimated that each hour of telemetry time would require a like period for further computer processing. This implies a computer facility of astonishing size, and to date, 2½ years later, the conception of the scheme has not yet been implemented. There are plans, however, of a more modest nature, to establish a limited computational capability at the Goddard Space Flight Center in the data reduction area.

The concept of digitizing telemetry data was rapidly translated into firm engineering design and the equipment built and operated in the short span of 8 months at the Goddard Space Flight Center. It was first utilized on the day of launch of Explorer VIII and has since gone through several evolutionary stages both to improve its performance and to modify its characteristics for subsequent satellites S-3 and probe P-14.

Concurrently, the success of the digitizing approach has resulted in the design of a more flexible automatic digitizing chain, which will be suitable for use on any of the forms of telemetry presently used in scientific earth satellites, and with pulse-code modulation (PCM), which is to be the mainstay of the later generation of scientific Earth satellites such as OAO, OGO, and OSO as well as on the application satellites such as communication and weather, etc.

The more sophisticated equipment is locally known as the STARS (Satellite Telemetry Automatic Reduction System) and will be in operation by mid-1962. Its features are described with greater detail below.

It is planned that the brute-force application of a number of STARS would be able to satisfy the demands for pre-processing the telemetry signals, with moderate capability of formatting it for *quick-look* printout as a means of assessing the performance of the experiments and the operation of data reduction processes. This would not solve the problem of further processing this enormous quantity of data in the digital computers. A solution to this problem seems to lie in our present plans to provide the STARS themselves with a modest amount of computational capability for performing the function of smoothing data (thus reducing its quantity) and in performing the simple functions of linearizing, scale factoring, offsetting, averaging, etc. This will result in removal of a large volume of simple but time-consuming arithmetic tasks from the computers. It would not appear to be feasible or even necessary, however, to provide each of the STARS with such a unit, since the data rates in them are slow enough to be handled easily by only one such unit if it were available to each. Accordingly it is planned to provide a central electronic control over several STARS which will undertake to provide these services. It will be programmable and will be directly connected to a general-purpose digital computer, the arithmetic unit of which will be available to the central control on an interrupt basis. It is envisioned that such an arrangement will make fuller use of the internal capability of the computer without overloading its input and output organs.

Signal-to-Noise Improvement and Demodulation Techniques

A large fraction of the telemetry data received from scientific satellites over the past 18 months was transmitted through the use of several forms of the pulse frequency modulation (PFM) telemetry system developed during the Vanguard Program. This system is described elsewhere in this issue.[1] Our present purpose is to describe the development of that part of the automatic processing system which provides the SNR improvement in and demodulation of the signals received at the central processing facility.

The PFM telemetry system is a time multiplexed system which usually conveys information in the instantaneous frequency in each of a series of short video-frequency bursts in the range of 2 to 4 kc, 5 to 15 kc or 10 to 30 kc. Each burst is separated by a blank which can be width modulated to convey slowly varying information.

The signal enhancement system design was based on the requirement that the post-detection SNR at the maximum expected range of the spacecraft must allow the signal to exceed the threshold of the frequency measuring devices to follow. In the PFM system utilizing the 10- to 30-kc frequency band, a data frame consisted of sixteen bursts, each at least 1 msec in duration. It was decided to obtain the required signal enhancement through the use of a bank of gated filters, only one of which would be active during any given burst. The resulting SNR improvement at the filter output then would be the ratio of the input signal bandwidth to the single filter bandwidth. In this case the 3-db bandwidth was chosen to be 1 kc resulting in an S/N improvement of at least 13 db (20 kc/1 kc). The actual improvement ratio is a function of the receiver bandwidth (usually greater than 20 kc). For the PFM system transmitting in the range of 5 to 15 kc with each burst nominally 10 msec in duration, system design called for each of the gated filters to have a 3-db bandwidth of 100 cps. Thus, 100 filter elements were necessary to cover the 10-kc band. Each filter provides an improvement of at least 20 db which again is subject to the actual receiver bandwidth used. Since the experimenters felt they needed about 1 per cent accuracy in the telemetry system, it was decided to use each filter element as the means of signifying the frequency in the burst. If a burst at any given instant in time appears in one of the 100 filters and is detected by that filter, the filter number is converted to an equivalent binary coded decimal number and stored for later readout. In the case of the 2- to 4-kc band, each burst was 3 to 5 seconds in duration. Again the gated filter concept was used, but here the 3-db bandwidth was selectable, resulting in a filter bank providing the necessary S/N improvement as required. In each system additional filter elements were provided on either end of the band to allow for unexpected drifts

[1] R. W. Rochelle, "Pulse-frequency modulation," this issue, pp. 107–111.

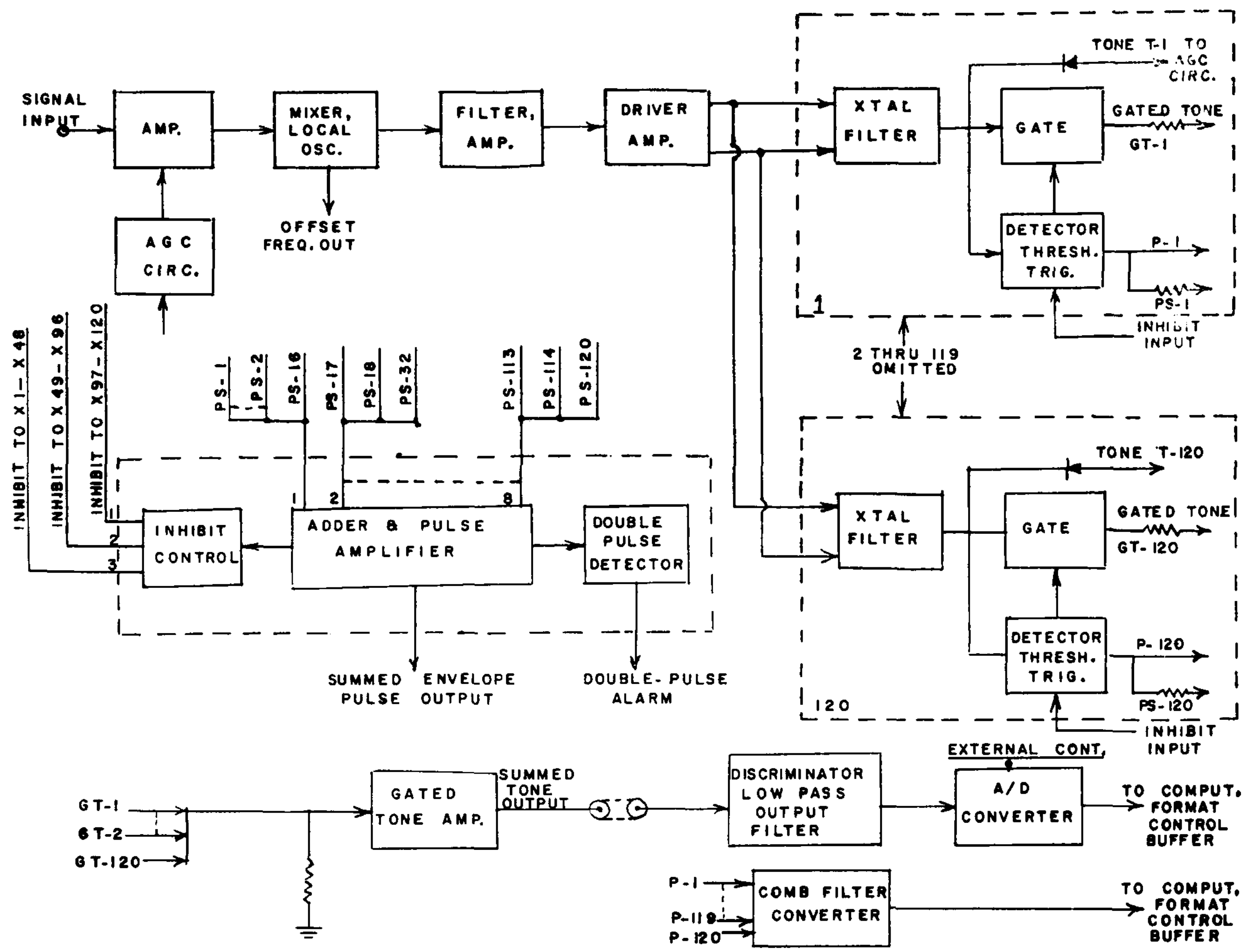

Fig. 1.

within the spacecraft system. The characteristics of each of these filter banks is given in the Appendix.[2]

Each filter bank is similar in concept and hence a general block diagram is shown in Fig. 1. The prime differences in the systems are the bandwidths of the individual filter elements and the manner in which the data is extracted from the bursts. All filter elements are single-tuned resonant circuits with the 3-db bandwidths in two of the units chosen to match the time duration of the bursts. In the third unit, the 3-db bandwidth was chosen to provide the maximum S/N improvement needed consistent with the expected SNR input and the minimum number of filter elements to cover the band of frequencies used. Each filter bank is supplied with integral logic necessary to insure that detection of a given tone burst occurs in that filter element which contains the greatest signal during the time of the burst. Detection of the presence of a tone burst is accomplished through the use of a fixed threshold detector following each filter element.

AGC circuitry is provided to maintain the signal level constant at the detector input with a $\pm$15-db change in signal level at the system input. High-frequency cutoff of the AGC loop occurs at about 3 cps, the intent being to minimize the effects of fading in the signal brought about by the spin of the satellite. At the time of detection of a burst or presence of a frequency within a filter element greater than that in any other, a gate is opened passing the enhanced signal through to the output. Thus, either the fact that detection has occurred or the frequency itself is used in the equipment following the filter bank in order to recover the data conveyed. In the first case, logic circuitry was designed to convert the filter element of a digital number which is ultimately stored on magnetic tape. In the second case, the enhanced frequency was passed through a pulse-averaging discriminator low-pass filter combination, the output of which was converted to a digital number in an analog to digital (A/D) converter and then stored on magnetic tape. Figs. 2–4 show the results obtained from each of the filter banks and the S/N improvement obtained in actual signals received from the specified satellites.

[2] This work was performed at Interstate Electronic Corporation, Anaheim, Calif., under contract to NASA.

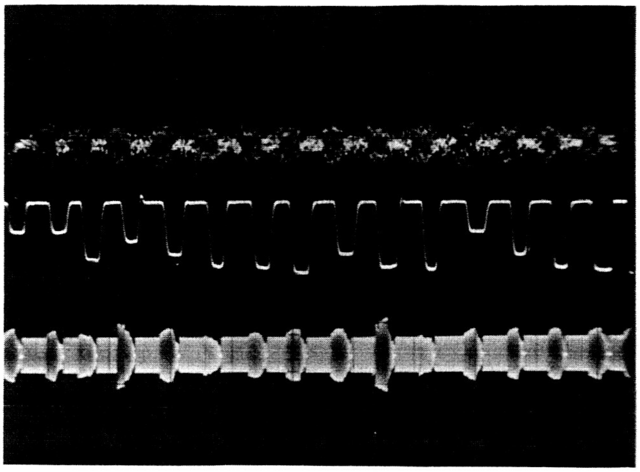

Fig. 2—The oscilloscope picture shown here indicates the signal transmitted from Explorer VIII at various stages in the ground processing equipment. The raw video signal at the receiver output is shown in the upper trace. The lowest trace shows the resulting output from the gated filters combined with a fixed frequency during the intervals between the bursts so that the discriminator that follows will have a continuous input signal. This eliminates the effect of level shifts during times when all the bursts do not gate through. The middle trace shows the discriminator output where the various levels from burst to burst are a measure of the frequency in the burst. The discriminator output is then followed by an A/D converter which converts the voltage levels to digital numbers at the proper time. The complete trace is about 40 msec long and the sync burst is the one barely showing at the right-hand margin.

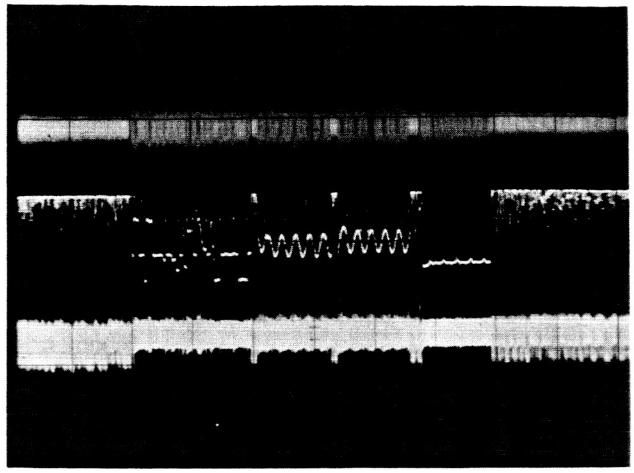

Fig. 3—This picture shows the signal received from Explorer X at various stages in the ground processing equipment. Again the upper trace is the signal output of the receiver and the lowest trace, the signal output of the gated filter. The middle trace is the discriminator output. In this case, the discriminator output is sampled at 4-msec intervals in an A/D converter. The first burst is the solar and earth aspect signal and is 5 seconds in duration; the middle two bursts are the output of two orthogonal Flux Gate Magnetometers, respectively (the sinusoidal variation is the result of the rotation of the spacecraft) and are 3 seconds in duration; the last burst is the output of a Plasma Probe nominally 5 seconds in duration (occasional malfunction in the spacecraft caused this burst to shorten as in this picture). The altitude of the spacecraft at this time is 226,000 km.

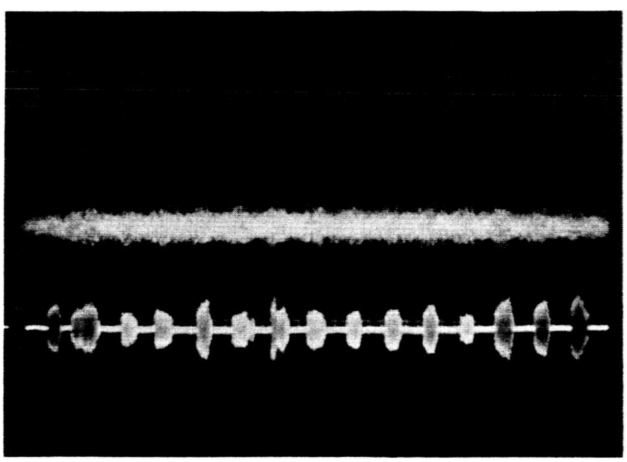

Fig. 4—This picture shows the signal received from Explorer XII at the receiver output in the upper trace and the gated filter output in the lower trace. Conversion to digital data is accomplished through the use of logic circuitry converting the 120 leads from the gated filter to a 3-digit decimal number. The signal received at this time was recorded at Woomera, Australia, when the spacecraft was at an altitude of 77,000 km. As in Explorer VIII, there are 16 channels here and the sync burst is the third burst from the left. This burst is 15 msec in duration preceded by a 5-msec gap; all other bursts and gaps are nominally 10 msec each.

It was hoped that an accuracy of 1 per cent would be attained in the analog data transmitted by this system when the SNR improvement was above the FM discriminator threshold in the one case and ±1 per cent where the filter elements themselves were used as the indicators. In practice, an average accuracy of about 3 per cent was obtained, but all results were strongly influenced by the fading characteristics of the telemetry signals and the skill and judgment of the various operators throughout the data acquisition and processing phases. In the second case, ±1 per cent has been achieved for the majority of the data processed. Because of the fixed threshold detector following the filter elements, degradation in the accuracy of the data is usually preceded by nondetection of the bursts, and hence it turns out that data is usually deleted before it is degraded to the point of uselessness. This indicates that there is a fairly sharp threshold effect inherent in the systems which could be relaxed in future designs. However, tests of the system using live satellite data have shown that operation now is within 3 to 6 db of that which could be obtained theoretically. Useful data have been obtained at satellite signal levels of −135 to −137 dbm.

All time-multiplexed telemetry systems rely on synchronization of the ground-detection equipment in order to specify unambiguously which of the measured data points within a frame belong with similar data points in succeeding frames. The method chosen for sending the framing information was to make one of the bursts longer than any other. Word sync could then be obtained by counting bursts following the frame pulse. At low SNR's, synchronization could not be maintained below the point at which there was still data recovered from the narrow-band filters without some method of "flywheeling" through periods of heavy fading. In the two cases described where there are sixteen bursts per frame, initial snyc was obtained by detecting the presence of the widest burst and then maintained by counting down a frequency derived through the use of envelope detection and narrow-band filtering of the burst train. This technique has proved highly successful and sync has been maintained over fades lasting as long as several seconds.

Automatic Data Handling and Processing

A principal objective of satellite missions is the extraction of data of all types. The volume of data obtained is very large, and the variety is limited only by the ingenuity and inventiveness of the experimenters. This is due to the fact that we are operating on a scientific frontier. Since the objective is the extraction of quality data, and not the test of system capability near its threshold, an adequate or better SNR is demanded and assumed by the automatic processing system. This may be achieved by a general over-all improvement of the communications system and/or signal conditioning and enhancement such as described above. As early as possible the system should provide a compact, unaltered, rapid-access library of all the data. It should also provide a versatile and flexible means of data manipulation. An essential consideration in the processing of satellite telemetry data is the correlation of data and satellite position. In general, the tracking solution is obtained independently. Therefore the processing system should insert ground time in the telemetry data. A digital form for the data as early as possible would seem to answer all of these requirements.

The problem is not technically different from what has been done in this field thus far. However, the scope is quite a bit wider than that encountered previously. The approach taken provides flexibility by making it possible to utilize a general-purpose computer for data shuffling and/or *bit fiddling*. In this way time to study, develop, and refine techniques for a more proper solution to the problem could be gained. In addition, going to this form early in the process gives the potential advantage of speedup of data transfer due to packing on magnetic tape as well as increased tape-handling speed.

The first system produced was developmental to provide this opportunity and to give capability to handle data with some automaticity as soon as possible. The telemetry format in greatest use at the Goddard Space Flight Center at that time was the PFM system.[3] As a result, the processing system was slanted to handle that form. As additional projects were developed, the telemetry system was modified and others were added; consequently, the ground automatic processing system was modified and expanded. These total modifications have resulted in the Satellite Telemetry Automatic Reduction System (STARS) concept. In this system a number of telemetry formats can be handled with dispatch and ease. The formats for which this system has been developed are PFM, PCM, FM/FM, and special-purpose digital.

The basic STARS system consists of the digitizing or encoding elements; the control logic including the snychronizer, programmer, and digital multiplexer; the time decoder; and the computer format control buffer, as shown in Fig. 5. The system accepts the regenerated and enhanced data, a derived clock as well as a standard frequency, and time code recorded with the data at the ground station. Synchronizing and digitizing of the data, where required, is accomplished, and the data interlaced with time as programmed is stored in a memory in the computer format control buffer. The output of the computer format control buffer is a digital magnetic tape in an IBM binary coded decimal format suitable for further processing by computer or off-line printer. Each element of the system is discussed separately below.

Digitizer—This portion of the system consists of a number of devices that convert the analog signal to a digital form. Depending upon the specific format to be processed, a more or less clean line can be drawn to describe each of the devices used.

1) Analog Multiplexer—This device is used to present any of a number of analog signals in sequence to

[3] Rochelle, *op. cit.*, p. 7.

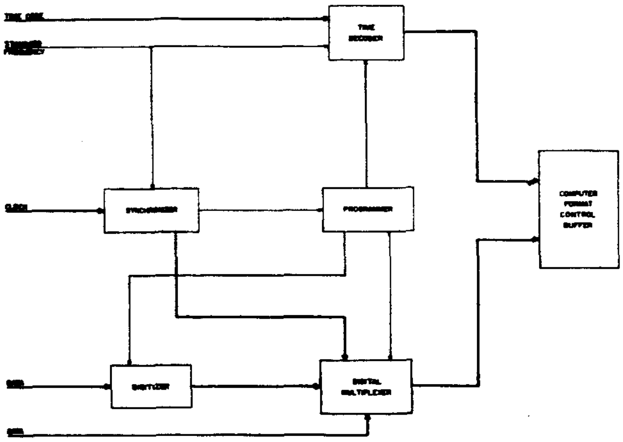

Fig. 5.

the analog-to-digital encoder under the control of the programmer.

2) Encoder—This instrument converts the analog sample to a digital form. Two different forms are used in this system. The first is a straight analog-to-digital converter of either the binary coded decimal or the binary type, in which a voltage is translated to a digital configuration. The second is a special device developed for use with the PFM format, and is called a comb filter encoder. This device accepts a single-element response of the comb filter, as described above, and encodes the data point in a compatible digital form. The output of each of these elements is a parallel digital word of a maximum 18 bits.

Control Logic—This system element contains the logic and circuitry to derive all synchronizing, sampling, and timing wave forms for the control of the system. It consists of

1) Synchronizer—This unit contains all of the shaping, counting, and comparing circuitry to derive frame and word, sync signals, and provides a sync *fly-wheel* to coast through periods of data dropout. Special-purpose digitizing of burst-blank widths is also incorporated. This device also contains an internal oscillator.
2) Programmer—This unit generates all of the control and programming of sampling, transfer, delete, etc. signals for both time and telemetry data encoding, routing and storage. When the system is operating on the internal clock, the suitably derived sampling frequency is developed here.
3) Digital Multiplexer—This unit consists of the digital gating necessary for the multiplexing of all digital data samples to a single set of parallel signal lines.

Time Decoder—The time decoder developed for this system is a completely solid-state device which is used to decode either of the two NASA time codes. These codes are the serial decimal time code and the binary coded decimal time code. It is capable of being operated in either mode and in each case it has three sub modes. These are

1) Multiple read-in, in which the time is continually read into the time register
2) The single read-in, in which the time is read into the time register once, and then clock pulses update the time register.
3) No read-in, in which no time decoding occurs but pulses are derived which update the time register

The time is stored in the output register under the control of the programmer mentioned above, so that as programmed time is interlaced with the telemetry data.

Computer Control Format Buffer—This device operates somewhat as a data sponge. It accepts either time or data input as commanded at a minimum rate of 5000 data points per second and multiplexes it to IBM tape format. This information is stored in a memory to provide buffering to the actual mechanical tape format required by the IBM equipment. In this device the block length, record length and all necessary gaps are established in addition to the various control functions and characters that are required. The output is a digital magnetic tape.

The utilization of these elements in each developmental phase depended upon the specific problem at hand. These can be designated as modes of the basic system, and are shown in the block diagrams in Figs. 6–8 (pages 130–132). Each has processed data as of this date. As mentioned previously, the resulting experience has lead to the concept of the STARS system (Fig. 9, page 133). In that system the common elements of control have been combined for efficient use, speed of change-over, etc. A patchboard is used to provide this flexibility.

A number of system improvements and developments are included or under consideration. These are possible in all of the major system elements with the exception of the time decoder. In the digitizer provisions can be made to accommodate further changes in telemetry format expecially in the PFM telemetry handling. In addition, various schemes for data compression can be implemented and arithmetice capability can be added to provide for linearization and scale factoring of the data. In the control logic adaptive control of programming can be included on a somewhat larger scale especially in the area of multiple system operation. In the computer format control buffer a number of possibilities exist. Specific implementation will depend on the need and the development of new requirements. Some of the possibilities, however, are reordering of the data, multiple output (*i.e.*, to more than one tape unit, printer, etc.) and multiple control characters so that data editing can take place while processing. Anywhere in the system, specific quick-look readout can be accomplished by utilizing the timing of the control logic and such devices as digital to analog converters and printers to expedite and improve control of the entire process. Specific emphasis is being placed on the develop-

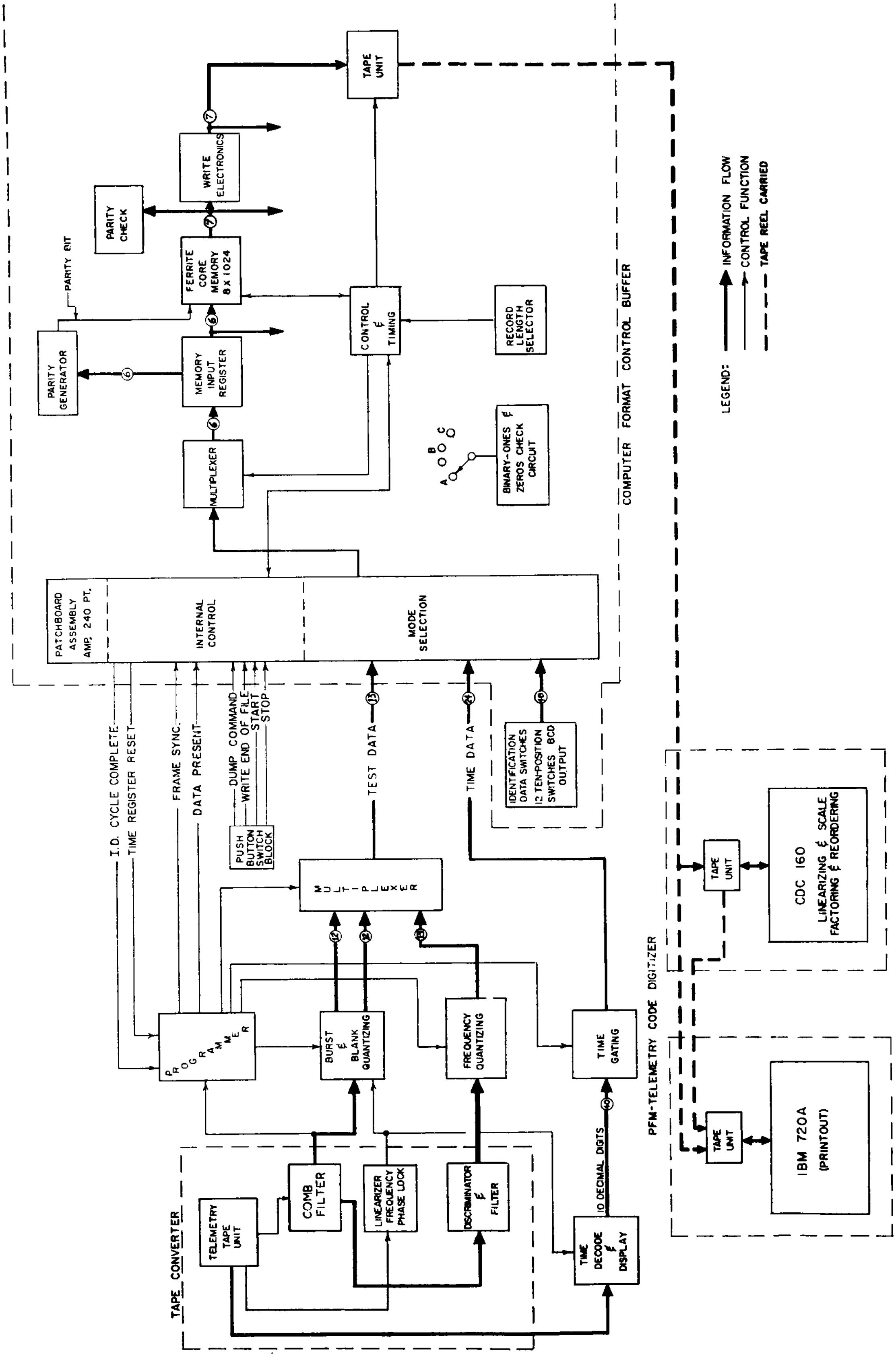
TAPE UNIT
WRITE ELECTRONICS
PARITY CHECK
PARITY BIT
FERRITE CORE MEMORY 8 X 1024
PARITY GENERATOR
MEMORY INPUT REGISTER
CONTROL & TIMING
RECORD LENGTH SELECTOR
MULTIPLEXER
BINARY-ONES & ZEROS CHECK CIRCUIT
A B C
COMPUTER FORMAT CONTROL BUFFER
LEGEND:
INFORMATION FLOW
CONTROL FUNCTION
TAPE REEL CARRIED
PATCHBOARD ASSEMBLY AMP. 240 PT.
INTERNAL CONTROL
MODE SELECTION
I.D. CYCLE COMPLETE
TIME REGISTER RESET
FRAME SYNC.
DATA PRESENT
DUMP COMMAND
WRITE END OF FILE
START
STOP
PUSH BUTTON SWITCH BLOCK
TEST DATA
TIME DATA
IDENTIFICATION DATA SWITCHES 12 TEN-POSITION SWITCHES BCD OUTPUT
MULTIPLEXER
PROGRAMMER
BURST & BLANK QUANTIZING
FREQUENCY QUANTIZING
TIME GATING
TAPE UNIT
CDC 160
LINEARIZING & SCALE FACTORING & REORDERING
PFM-TELEMETRY CODE DIGITIZER
TAPE UNIT
IBM 720A (PRINTOUT)
TAPE CONVERTER
TELEMETRY TAPE UNIT
COMB FILTER
LINEARIZER FREQUENCY PHASE LOCK
DISCRIMINATOR & FILTER
TIME DECODE & DISPLAY
10 DECIMAL DIGITS

Fig. 6.

ments and improvements mentioned. Reliability of the equipment is of extreme importance as the system becomes more complex. Basic system speed has been adequate for a single type of processing. As integrated and multiple operations are included, some increase in speed in selected areas is indicated.

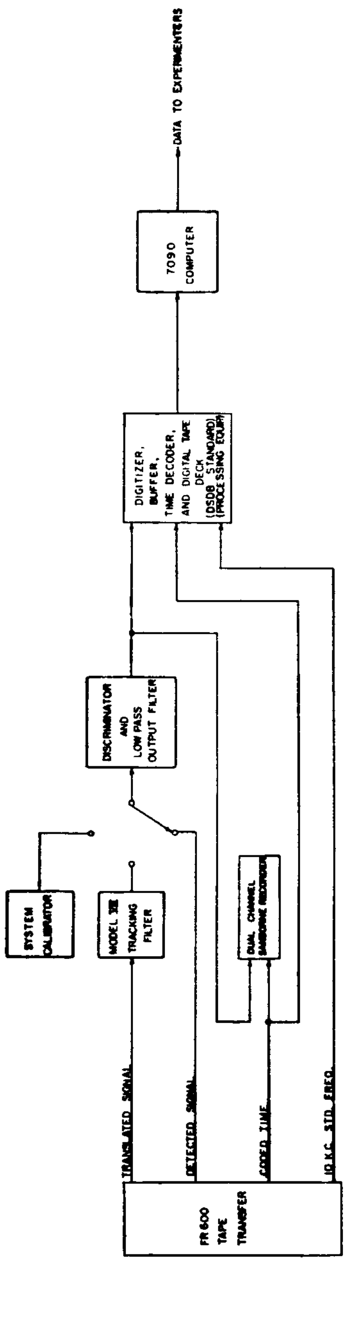

Fig. 7.

Conclusions

It will be apparent to people who have been exposed to problems of processing large amounts of heterogeneous data that there is nothing revolutionary in the solution to this problem. It will be noted, however, that the problems of weak signals, fluctuations and large amounts of data exceed in degree most prior experience. It may be interesting to assess the success of this concept in reducing satellite telemetry data.

First, it must be admitted that the automatic processor we have described has not yet *reduced* data in the literal sense of the word. This is because the digital tapes turned out so far have not, with minor exceptions, been run through the digital processor (or computer) to actually remove the great amount of redundant information inherent in the telemetry and the uncertainties introduced in the transmission link. In addition, the term reduction includes the steps required to put the information in forms having greatest usefulness to the experimenter. These further steps have not yet been accomplished due to limitations of manpower and money. It is hoped that these limitations will rapidly be overcome by additional support to the data reduction efforts.

It should be understood that at the time many current satellites were conceived there was relatively little consideration of what would be necessary to reduce the data produced. Many experimenters believed, and indeed some still insist, that their data would be presented to them in the form of oscillographic charts, as they would be in the experimenter's own laboratory. In many cases this approach is ruled out by economic and logistic reasons. When the first satellite to have its data processed by our automatic machines went aloft, a digital record of 200,000 data points was available in printed form the next day. This was taken to the project scientist, and the format was carefully explained to the experimenters. They were instructed how to extract the information from their respective data channels and informed that additional steps to reduce the data in the computer would be taken. Sometime later, when it became apparent that this would be considerably delayed, it developed that the experimenter had extracted a considerable amount of information from the printed record by hand. So much so, in fact, that they had more scientific papers to write based on this information than they could currently manage to do! This is not intended to indicate that actual reduction in digital machines should not be undertaken, but merely illustrates the power of the technique as developed so far.

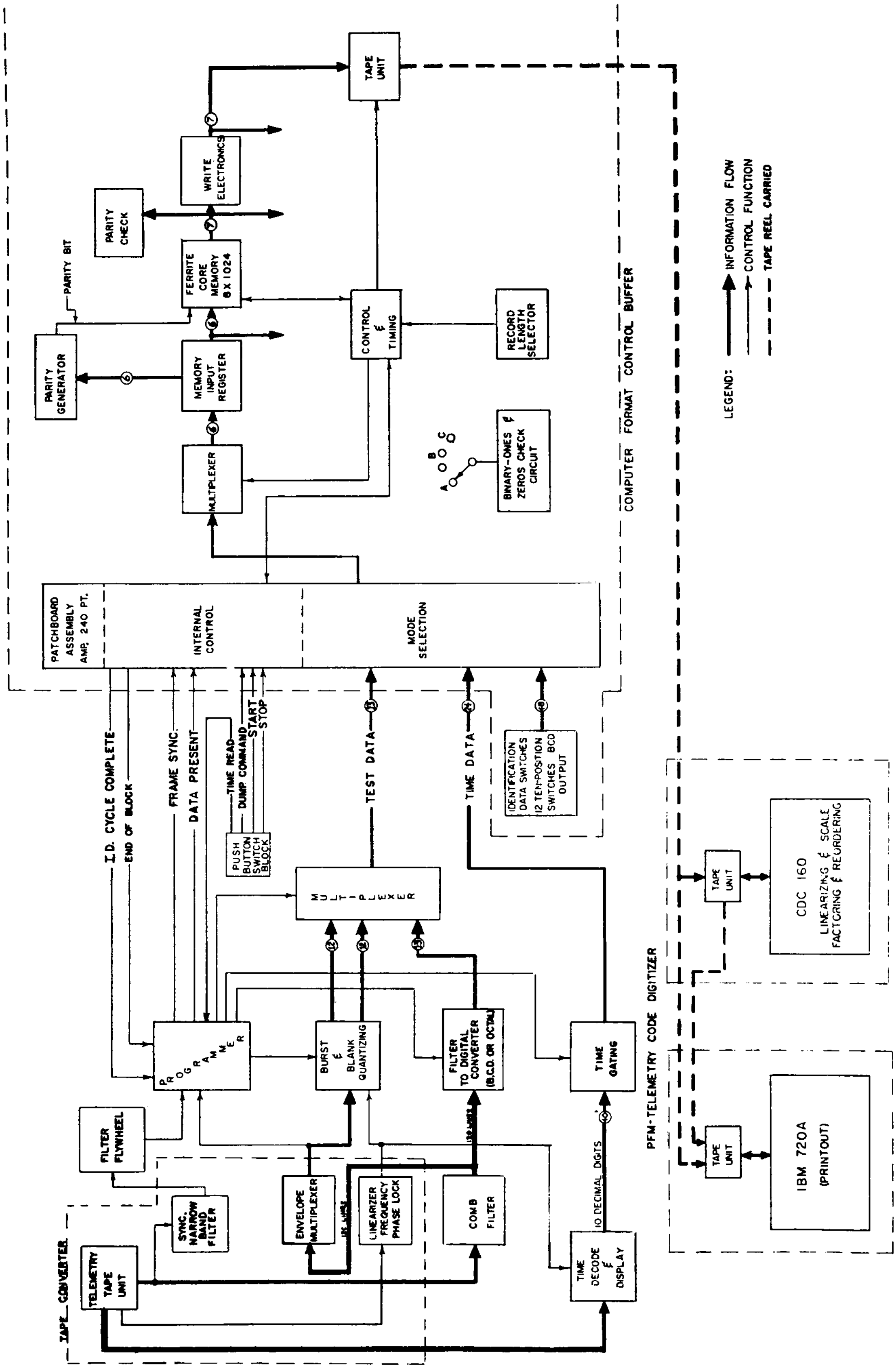
TAPE UNIT
WRITE ELECTRONICS
PARITY CHECK
FERRITE CORE MEMORY 8 X 1024
PARITY BIT
PARITY GENERATOR
MEMORY INPUT REGISTER
CONTROL & TIMING
RECORD LENGTH SELECTOR
MULTIPLEXER
BINARY-ONES & ZEROS CHECK CIRCUIT
PATCHBOARD ASSEMBLY AMP. 240 PT.
INTERNAL CONTROL
MODE SELECTION
COMPUTER FORMAT CONTROL BUFFER
LEGEND:
INFORMATION FLOW
CONTROL FUNCTION
TAPE REEL CARRIED
I.D. CYCLE COMPLETE
END OF BLOCK
FRAME SYNC.
DATA PRESENT
TIME READ
DUMP COMMAND
START
STOP
PUSH BUTTON SWITCH BLOCK
TEST DATA
TIME DATA
IDENTIFICATION DATA SWITCHES 12 TEN-POSITION SWITCHES BCD OUTPUT
MULTIPLEXER
PROGRAMMER
BURST & BLANK QUANTIZING
FILTER TO DIGITAL CONVERTER (B.C.D. OR OCTAL)
TIME GATING
FILTER FLYWHEEL
SYNC. NARROW BAND FILTER
ENVELOPE MULTIPLEXER
LINEARIZER FREQUENCY PHASE LOCK
COMB FILTER
TIME DECODE & DISPLAY
10 DECIMAL DIGITS
TELEMETRY TAPE UNIT
TAPE CONVERTER
PFM-TELEMETRY CODE DIGITIZER
TAPE UNIT
CDC 160
LINEARIZING & SCALE FACTORING & REORDERING
TAPE UNIT
IBM 720A
(PRINTOUT)

Fig. 8.

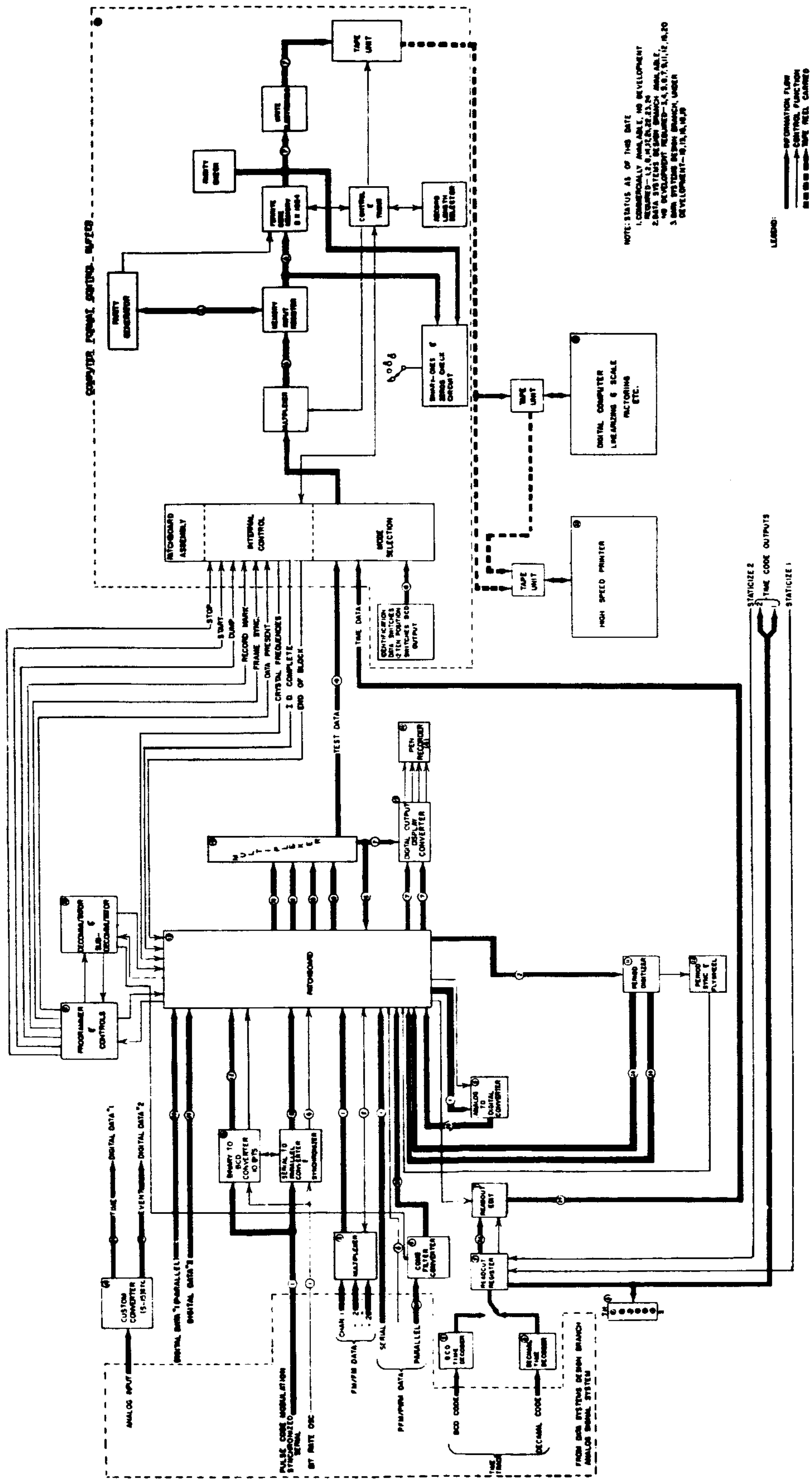

Fig. 9.

Appendix

Part A

Specifications:

Input frequency range	4 to 35 kc
Number of filters	32, 16, or 8 (selectable)
Filter bandwidth	1.0, 2.0, or 4.0 kc (3-db bandwidth)
Center frequency spacing	1.0, 2.0, or 4.0 kc
Input level	0.02 to 2.0 vrms burst level
Input impedance	Approximately 20 k ohms
Detection threshold	
Initiation	0.6 of filter-input burst amplitude
Termination	0.4 of filter-input burst amplitude
AGC	Less then ±0.5-db variation at filter inputs with 20-db input variation at 3.0-cps rate, or 40-db variation under approximate steady-state conditions
Limiting	Less that ±0.5-db variation at filter inputs with 2 to 1 pulse-to-pulse level variation
Outputs	
32 individual gated tone-burst outputs	
Frequency	Input tone-burst frequency plus 50 kc
Frequency range	Equal to 3-db filter bandwidth
Burst length	Corresponds to input burst length as determined by detection thresholds
Peak amplitude	1.5 to 2.0 v peak to peak
Impedance	Less than 1 k ohms

Part B

Specifications:

Input frequency range	1.5 to 4.475 kc
Number of filters	120, 60, 30, or 15 (selectable)
Filter bandwidth	25, 50, 100, or 200 cps
Center frequency spacing	25, 50, 100, or 200 cps
Input level	0.05 to 2.0 vrms burst level
Input impedance	12 to 30 k ohms (depending on bandwidth setting)
Outputs	
120 individual envelope pulse outputs	
Pulse description	Positive going pulse, −11 off to 0 on, less than 1 μsec risetime
Maximum load	250 μa in off position, 25 ma in on position
1 gated tone-burst output	
Frequency	Input tone-burst frequency +250 kc
Amplitude	Adjustable—nominally 1.5 v peak to peak
Output impedance	Less then 1 k ohms
1 summed envelope pulse output	
Impedance	Less than 1 k ohms
Risetime	Less than 2 μsec
1 250-kc offset reference	
Frequency	250 kc
Amplitude	1 vrms nominal

Part C

Specifications:

Center frequency	100 or 200 cps
Input level	0.05 to 2.0 vrms burst level
Input impedance	12 to 30 K (depending on bandwidth setting)
Outputs	
128 individual envelope pulse outputs	
Pulse description	Positive going pulse, −11 off to 0 on, less than 1 μsec risetime
Maximum load	250 μa in off position, 25 ma in on position
1 gated tone-burst output	
Frequency	Input tone-burst frequency +250 kc
Amplitude	Adjustable—nominally 1.5 v peak to peak
Output impedance	Less than 1 k ohms
1 summed envelope pulse output	
Impedance	Less than 1 k ohms
Risetime	Less than 2 μsec
1 frame identification pulse	
Leading edge time	Determined by setting of frame sync control
Duration	15 ma
Amplitude	−12 to 0 v
Risetime	Less than 1 μsec
1 250-kc offset reference	
Frequency	250 kc
Amplitude	1 vrms nominal

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